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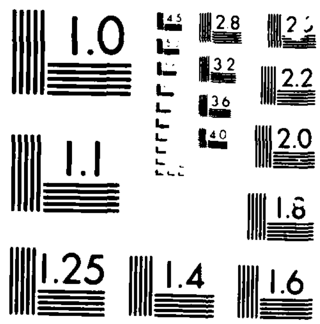

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FOREIGN TECHNOLOGY DIVISION

INTERNATIONAL AVIATION

(Selected Articles)

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THE APPLICATION OF WINGLETS ON TRANSPORT-5 AIRCRAFT

Yang Daxi

"Winglets" is a technique to reduce drag which is being studied overseas. The comrades of technical groups in factory 102 of Chinese Civil Aviation conducted test flight studies with the winglets installed on T-5 aircraft. Significant drag reduction was achieved. /2

Editor

The applications of tip extension or winglets to reduce the induced drag have been given a lot of attention both domestically and internationally in recent years. For most transports, the induced drag accounts for approximately 30% of total drag while cruising. This percentage is even greater for lower speeds. For the T-5 biplane, the induced drag is about 55 6% of total drag during the takeoff climb, 33% during cruising and 58% during regular climbing. The uses of tip extension or winglets, therefore, hold potential promise to reduce drag. There are quite a number of T-5 transports in China. The applications are also extensive. For this reason, we started the research of adding winglets to the T-5s since August, 1982.

The design and installation of winglets

Referring to foreign wind tunnel and flight test results, combining with the structural characteristics of the T-5 transports, we designed the geometric configuration of the winglets as in Figure 1. The span of the winglet is 24.5%c (wing chord), chord at the root is 16%c, leading edge sweepback is 21°. In order to delay the flow separation at the root, the front of the winglet is designed with greater camber and twist. The air flow along the entire chord of the winglet root gradually changes to the free flow direction, thus peak value of pressure distribution is reduced to a minimum. The central arc of each cross section of the winglet is a circular arc. When the wing is at a positive angle of attack, the tangent of each central arc at the leading edge of the winglet will approximate more closely the local air flow direction. Based on the best results obtained from experiments, we chose the angle between the tangents of the front and rear central arcs at the root of the winglet to be 20°. This angle ψ is drastically reduced with the increase of distance from the root (reduction about one-half with the distance increase approximately 6% of the wing tip chord). That is to say, the curvature of every cross section of the winglet is NACA-0012. Preliminary experiments show that the drag reduction effect is the best when three winglets are installed. More winglets will not increase the effect significantly, but the structural load will be increased correspondingly. Therefore, three winglets are used on both wing tips of the T-5 transport. The leading edge of the front winglet is 36%c from the leading edge of the wing. The angle between the front winglet and the relative wing chord surface is 30 degree upward. The angle for the middle winglet is 15 degree upward while for the rear winglet it is zero degrees. The arrangement of these winglets will alter the local air flow direction. The spiral flow which circulates the wing tip from underneath the wing to the upper surface is streamlined to a near flat flow. It also generates partial thrust force momentum. The winglets are attached to a cylinder of 2.18 meters length. The end of the cylinder has the parabolic contraction. The cylinder is adhered to the wingtip with a "glove" approach. The axis line is parallel to the chord and is 63 mm above the wing tip chord. The arrangement of the winglets on the wings are depicted in Figure 2. The condition after installation of the winglets is shown in Figure 3.

Flight test results

We conducted actual flight tests using T-5 transport serial no. 8077 since October, 1982. Comparisons are made between test results with or without winglets. The flight tests were conducted under empty aircraft (aircraft weight 4000 kilograms) and total weight (aircraft weight 5250 kilograms). The tests

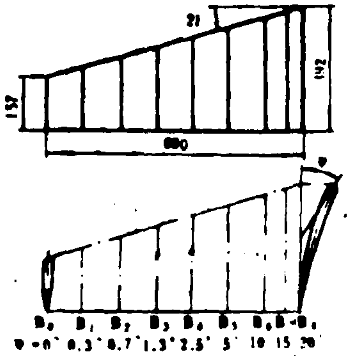

Figure 1. Major geometric characteristics of winglets.

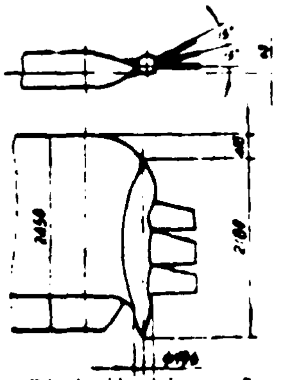

Figure 2. Distribution of winglets on the wings (unit: millimeter)

Figure 3 Winglets installed on the wings.

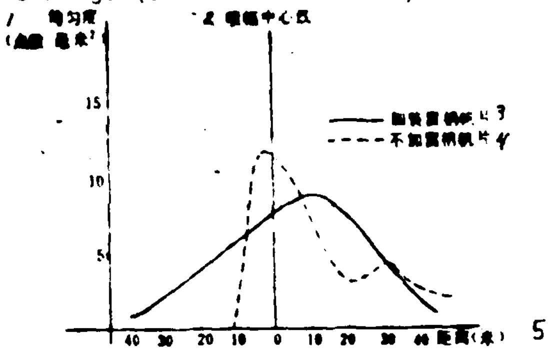

Figure 4. Curves showing total evenness of droplet distribution from three sprays by aircraft no. 8077 with winglets and aircraft without winglet.
1--evenness (no. of drop/mm^2); 2--median line of spray span; 3--with winglet; 4--without winglet 5--span coordinate

The performance comparison for aircraft 8077 with winglets.

1 机号 8077	W=4000公斤 2		W=5250公斤 2	
	3 改善程度		3 改善程度	
	4 增加 (%)	5 减少 (%)	4 增加 (%)	5 减少 (%)
6 最大平飞速度	1.8		1.9	
7 巡航平飞速度	2		2.4	
8 爬升率	8.7		29	
9 爬升时间		8		32.5
10 下滑率		11.1		8.3
11 下滑时间	12.4		9.1	

1 - aircraft no.; 2 - kg; 3 - performance improvement; 4 - increase; 5 - decrease; 6 - 6 - max. level flight speed; 7 - cruising speed; 8 - climb rate; 9 - climbing rate; 10 - glide rate; 11 - gliding time.

included various disciplines such as takeoff, climbing, high speed horizontal flight, cruise, 45° slope, glide, loss of speed, side drift, downward drift, pull-up at low altitude and landing. In order to test the improvement of fuel efficiency, round trip test flights between Shanghai and Hofei were also conducted. The winglets reduce the vortex at the wingtip hence the possibility of increasing the evenness as well as the decrease of dispersion area of the chemicals being spread by the transport has to be considered. Several comparison flight tests were conducted to distinguish the differences for the dispersion of chemical powders and liquids.

The flight tests clearly show that the aircraft performance is /3
highly improved with the winglets. It can be obtained from the variation of the polar curve that for an aircraft of total weight 4740 kilograms under cruising speed of 200 km/hr and lift coefficient 0.3436, the winglets reduce the total drag by 4.31% while the induced drag is reduced by 22.8%.

The table (page 3) shows the flight test results under standard atmospheric condition. It can be seen from the table that under full load (5250 kilograms) the climb rate is increased by 29%. The effect is very significant.

A test flight to verify the improvements on service ceiling has also been conducted. The results show an increase of practical service ceiling up to 1000 meters for aircraft with winglets. This is a very important improvement for aircraft operating in plateau areas. From the calculation of performance, it is estimated that during cruise flight with unchanged horsepower setting (i.e., engine maintaining an rpm of 1700 and inlet air pressure of 700 mm Hg), then for aircraft with winglets the fuel consumption can be reduced by 2.0%. If constant cruising speed is maintained, then fuel consumption can be reduced by 4.58%. The actual test flight of cruise showed 2.5% for the former and 5.1% for the latter. The actual performances exceeded calculated

expectations under both conditions. Also, the experiments for spraying chemicals on agricultural plants showed that with winglets the range of spray was greater. Spray was found to be low, flat and even. Figure 4 is the actual test results from aircraft with and without winglets. Each aircraft sprayed three times. The curve shows total evenness of droplets.

In addition, the test flight pilots reflected that aircraft with winglets were easier to control and had better response. During steep slope or side glide flights, the aircraft is found to be stabler and easier to control. Aircraft 8077 with winglets has been flying for over 320 hours since April, 1983. It has carried regular flight, training and various operational missions. The condition of the aircraft is normal. The improvement of its performance is found to be consistent with that found during test flights. Winglets were installed on another T-5 transport with serial number 8242 since November, 1984. The aircraft took part in and passed the test flight conducted by the Bureau of Civil Aviation to verify its performance. The effects of winglets were totally proven.

PAYLEY OF DASSAULT BREGUET, FRANCE, TALKS ABOUT THE AERODYNAMICISTS OF THE YEAR 2000

Zhong Lingyen

Aerodynamics science is a branch of applied science in fluid mechanics. It is the most complicated science within the scope of mechanics. Being an aerodynamist, he has to understand, predict as well as compute the temperature, pressure and velocity of every point in the flows which for most of the time is non-uniform or turbulent. In order to be able to reason with these non-linear, complicated phenomena, he has to not only have an overview for the phenomena, but also have capabilities to analyze and infer.

The aerodynamists*of the 40's

Aerodynamists of this period usually depended on direct observation to proceed with their work. Based on their achievements, they can be called "artists" or "technicians who know how to fix things". They "create" things based on the experiences accumulated since man's first flight. They started using simulation equipment of high mass, yet their research of the science was restricted to an understanding of the overall characteristics. They knew nothing at all as far as flow field details were concerned.

As for design tools, they only had a limited quanity. Their approach was a logical method which is based on interrelationships between speed and pressure, lift force and circulation. Through the use of silk thread to display flow condition, they had a preliminary understanding that the lift force had a trend of elliptic distribution. Also, they realized that drag force is closely related with aero-viscosity and gas flow separation.

The aerodynamists of this period almost all had a hobby. They felt that they had a special quality of instinct.

*Translator's Note: In this article, the word "aerodynamists" should have been spelled "aerodynamicists".

The aerodynamists of the 60's

Most of the areodynamists of this period depended on wind tunnel testing data to proceed with their design work. One reason was because of the use of accurate scale equipment, therefore, the measurement accuracy was greatly improved. The other reason was that they started to understand the extreme complexities of supersonic, hypersonic and especially transonic flows. They wrote large amounts of wind tunnel testing reports. They hoped to find the similarities between wind tunnel experiments and actual flights. The reason was to solve all kinds of complicated aerodynamic problems when they tried to improve the performance of aircraft or missiles. In order to understand the vast amout of wind tunnel testing data from a number of research institutes from all over the world on parasonic, transonic, supersonic and hypersonic flows, they were in great need of a larger, more advanced design and research tool than their colleagues of the previous generation.

The basic research work of this period provided the aerodynamists with a lot of information concerning incompressible flows. They understood the flow characteristics of rear-sweepback wings and wing type linear lift force section. They also understood supersonic flow as well as the phenomena of propagation along Mach line of the weak perturbation. However, hypersonic flows, especially transonic flows, were still very strange to them at that time. They were also amazed by the non-linear aerodynamic phenomena caused by agitated waves.

Design tools and knowledge for the 60's were mostly related with two dimensional transonic and supersonic flows. These were supplemented by the concepts of boundary layer and separated flows. Otherwise the reasoning of the above flows would not have been realistic. When they lack an overview of the flow field, methods such as smoke-flow, water-flow and strip-shadow were used for observation.

Major achievements of the aerodynamists of this period were that they had acquired a large amount of reliable, reproducible data through measurements. These measurements made it possible to study the aerodynamic properties of aircraft and missiles through repeated experiments and adjustments.

The aerodynamists of the 80's

Before even the 80's, general aerodynamists started to face the challenges from experts of certain specific areas in aerodynamics. These experts doubt the capabilities of general aerodynamists to describe realistically and effectively the aerodynamic properties of new vehicles. Only after the employment of computers were these experts able to demonstrate through computation the practicality of the mathematical models for a certain aerodynamic problem. This should be considered from two different points of view: one is the basic experimental measurement towards the elementary physical phenomena; and the other one is the ability of such mathematical models should be capable of solving specific problems.

Aerodynamists of previous generation depended on the effects after the modifications of external configuration to verify their instincts. The success most of the time relied on the experiences they accumulated or, sometimes pure luck. They really did not fully understand the mechanism very well. The aerodynamists of the 80's, however, directly verified the effectiveness of the models used. The improvements by using the models were examined. Whether the improvements should be adopted in reality or not was decided. On the contrary, the question whether the models were accurate enough, whether they were appropriate for the physical phenomena studied, could be studied. In the meantime, more accurate supplementary measurements could be conducted to remove certain doubts.

The development of aerodynamics of today relies on the ability of mathematical simulation, that is the ability of using numerical analysis methods to solve related partial differential equations. The possibility of using more and more accurate computational flow to establish a mathematical model for the complicated non-uniform turbulence is another foundation for future development.

It is very difficult for the general aerodynamists to follow these rapidly developing mathematical simulation techniques due to the fact that their daily work deals with mostly verifying the wind tunnel testing results. The results from these wind tunnel experiments sometimes deviate from theoretical values. Therefore, flight tests are usually necessary for final judgement in the long run.

If it could be said that aerodynamists were requested to provide accurate measurements before, then the aerodynamists of the 80's were requested to provide accurate computations.

The aerodynamists of the year 2000

These will be aerodynamists of a brand new generation. They will be able to conduct temperature adjustments on their measuring equipment during testing. They will also have plenty of knowledge of programming, gliding, substitution and the application of routines and subroutines, these knowledge will be useful when they perform numerical calculations. They will be able to /52 correctly use the computers based on the problems being studied. They will also manage the computers as well as its peripherals.

It will be customary to solve systematically the ideal fluid mechanics equations; boundary layers and mixed equations. However, it will take a few decades to establish a model for turbulence with certain accuracy, even with the increase of computer storage as well as computation speed.

If we said that the aerodynamists of the 60's were restricted by the methods and equipment available, therefore, they were unable to fully understand the mechanisms of local turbulence and three-dimensional flows, then a different situation will occur for the aerodynamists of the year 2000. They will have a tendency to try to solve a very simple problem with complicated methods, due to the fact that they will have enough resource to perform computer simulations as well as conduct accurate measurements. The expense then will be high. Hence, the aerodynamists of the year 2000 will be encouraged to equip themselves with the ability to use simple and small equipment for problem solving, such as small scale wind tunnels, small scale models and small computer systems.

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